APPARATUS, METHOD AND SYSTEM FOR SINGLE WELL SOLUTION-MINING

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BACKGROUND OF THE INVENTION

This invention relates to solution-mining of subterranean materials. The following discusses the disclosed solution-mining invention as applied to trona, but it is understood that this solution-mining invention applies to all subterranean materials.

The subterranean material trona, also known as natural soda ash, is a crystalline form of sodium carbonate and sodium bicarbonate, known as sodium sesquicarbonate, having the formula $Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$. Worldwide, deposits of natural trona are rare, but the world's largest known deposit is located in the Green River Basin of southwestern Wyoming. Smaller deposits of trona are found near Memphis, Egypt and the Lower Nile Valley, widely throughout the soda lakes of Africa, Armenia, and Iran, and in the alkali deserts of Mongolia and Tibet. From natural trona, the primary end product is soda ash. In fact, Wyoming produces 90% of the processed soda ash in the United States and 30% of the world's supply. Other end-products from trona include sodium bicarbonate, caustic soda, sodium sulfite, sodium cyanide and sodium phosphate. Improved and cheaper processes for mining trona from natural deposits are desired.

Mining is an age-old approach for removing subterranean materials, e.g., trona, nahcolite, dawsonite, wegscheiderite, thermonatrite, pirssonite, natron, gaylussite, shortite, halite, and other

salts, minerals, and so forth. Many deposits of subterranean materials, however, do not permit commercially viable extraction, whether through underground mechanical mining or solution-mining. For example, not even 10% of known trona deposits permit commercially viable underground mechanical mining, and trona solution-mining has not been economical.

Underground mechanical mining requires deep shafts to remove the subterranean material, and ever-deeper shafts are used as more material is extracted. In addition, mechanical mining is people-intensive. This creates a dangerous operating environment.

After lifting the material to the surface, the material is calcined to expel volatile components, such as carbon dioxide. Calcination is an energy-intensive processing step that affects the economics of mechanical mining. After calcination, the calcined material is recrystallized in aqueous solution, collected, dried and ready for further processing or shipping.

Solution-mining is a touted alternative to mechanical mining, but solution-mining has not proven as economical as desired. Solution-mining of subterranean materials, in particular, trona, is possible using hot water or alkaline solutions. For example, U.S. Pat. No. 2,388,009 (Pike) discloses the use of a hot water or hot carbonate solution as the mining fluid. See also U.S. Pat. Nos 2,625,384 (Pike et al.); 2,847,202 (Pullen); 2,979,315 (Bays); 3,018,095 (Redlinger); 3,050,290 (Caldwell et al.); 3,086,760 (Bays); U.S. Pat. No. 3,184,287 (Gancy); 3,405,974 (Handley et al.); U.S. Pat. No. 3,952,073 (Kube); U.S. Pat. No. 4,283,372 (Frint et al.); 4,288,419 (Copenhafer et al.); and U.S. Pat. No. 4,344,650 (Pinsky et al.), all of which are incorporated herein by reference. These disclosures, and other documented solution-mining processes, reveal use of two or more of the following economic drains on commercial viability: high temperatures, high pressure calcination, hydraulic fracturing ("fracturing"), and two wells, wherein one well is for injection and one well is for production, see e.g., U.S. Pat. No. 4,815,790,

Rosar, et al.; U.S. Pat. No. 4,344,650, Pinsky, et al.; U.S. Pat. No. 4,252,781, Fujita, et al.; U.S. Pat. No. 4,022,868, Poncha, et al.; U.S. Pat. No. 4,021,526, Gancy et al.; and U.S. Pat. No. 4,021,525, Poncha, all of which are incorporated herein by reference. Fracturing rarely fractures only the material to be removed, so injecting hot water or alkaline solution dissolves other materials, including salts, and contaminates the subterranean material product collected from the production well. Collection of contaminated subterranean materials is yet another economic drain to commercial viable solution-mining processes.

In addition to solution-mining of trona, various U.S. patents disclose solution-mining of nahcolite (predominantly $NaHCO_3$). For example, U.S. Pat. No. 3,779,602 (Beard et al.) and U.S. Pat. Nos. 3,792,902 (Towell et al.), and U.S. Pat. No. 3,952,073 (Cube) and U.S. Pat. No. 4,283,372 (Frint, et al.) disclose basic solution-mining of nahcolite and wegscheiderite (predominately $Na_2CO_3 \cdot 3NaHCO_3$), all of which are incorporated herein by reference. Like the trona solution-mining processes, however, these nahcolite and wegscheiderite solution-recovery processes also possess economic drains on commercial viability.

A need, therefore, exists for improved solution-mining of subterranean materials through improved, more efficient methods and systems.

SUMMARY OF THE INVENTION

The claimed invention is a method, system, and apparatus for solution-mining of subterranean materials. According to a first aspect of the invention, a method is provided for solution-mining of a subterranean material, the method comprising injecting a fluid into an elbow well, the fluid forming a subterranean mixture with the subterranean material, and collecting the subterranean mixture from the elbow well. According to another aspect of the invention, a system is provided for solution-mining of a subterranean material, the system comprising a means for injecting a fluid into an elbow well, the fluid forming a subterranean mixture with the subterranean material, and a means for collecting the subterranean mixture from the elbow well. According to still another aspect of the invention, an apparatus is provided for solution-mining of a subterranean material, the apparatus comprising an injection tube, wherein the injection tube has an injection tube inner diameter of sufficient size to allow for injection of a fluid for mining of a subterranean material. The apparatus further comprises a production casing, wherein the production casing has a production casing inner diameter of sufficient size to allow for production of a subterranean mixture of the fluid and the subterranean material between an outer surface of the injection tube and an inner surface of the production casing.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic of the cased elbow well drilled into a bed of a subterranean material, wherein the elbow well comprises an injection tube, a production casing, and a production tube that is connected to a pump to help lift the subterranean mixture in the cavity to a collection location, here, the earth's surface.

Figure 2 is a cross-sectional view of the initial cavity in the elbow well.

Figure 3 is a cross-sectional view of the cavity in the elbow well, wherein the cavity is larger than in Figure 2.

Figure 4 is a cross-sectional view of the cavity in the elbow well, wherein the cavity is larger than in Figure 3.

DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

The disclosed solution-mining invention is a device, method, and system for solution-mining of subterranean materials, such as trona, nahcolite, dawsonite, wegscheiderite, thermonatrite, pirssonite, natron, gaylussite, shortite, halite, and other salts, minerals, and so forth. Although this detailed disclosure focuses on the subterranean material trona, it is understood that the disclosed device, method, and system for solution-mining applies to all solution-minable subterranean materials.

In one example embodiment of the claimed invention, seen in **Figure 1**, an elbow well **15** is drilled into a bed **30** of the subterranean material **25** being mined. An elbow well **15** is a well that begins at the earth's surface **70**, and first penetrates vertically before penetrating horizontally. Although the elbow well **15** does not necessarily resemble the shape of a human elbow, there is a vertical portion that eventually turns to a horizontal portion. For trona, the estimated depth **160** for mining is 2000 feet below the earth's surface **70**. Both an injection tube **45** and a production tube **60a** are located in the elbow well **15**, wherein 3-½" J55 tubing is used in one example for the injection tube **45**, but other sizes and types of tubing will occur to those of skill in the art without departing from the scope of the present invention. A fluid **10** is injected into the injection tube **45**, wherein the fluid **10** reacts with the subterranean material **25** to create a mixture **55** (e.g., a solution) and a cavity **50**. The mixture **55** flows between the injection tube **45** and the production casing **60b**. In another example embodiment, a pump **140** is attached to the production tube **60a** to help lift the mixture **55** to the collection point **65** (here, the earth's surface **70**).

Fracturing is unnecessary in many embodiments of the invention, because the injection tube **45,** production casing **60b**, and production tube **60a** are in the same well **15**. The elbow well **15**,

in some embodiments, is over 3000 linear feet in length **155** within the bed **30** of the subterranean material **25**.

According to another embodiment of the invention, seen in **Figures 2-4**, the cavity **50** expands as more fluid **10** is injected into the well **15** dissolving more subterranean material **25**. The cavity **50** expands outward from the end of the elbow well **15**, and therefore the cavity **50** propagates back to the well **15**. In the event that a collapse of the cavity **50**, or other obstruction, reduces the flow of the mixture **55**, the injection tube **45** is perforated in some embodiments to permit further amounts of the mixture **55** to be collected. Alternatively, rather than perforation, the injection tube **45** is withdrawn, partially, until debris from the collapse is clear and flow of the mixture **55** is raised to an acceptable level.

High pressures of operation may cause the material **25** in the mixture **55** to escape before collection of the subterranean material mixture **55**. Low pressures of operation, however, reduce the total collection of the subterranean material **25**, because the cavity **50** may collapse prematurely. Selection of the well pressure to avoid these problems should be observed. At present, there is no known empirical method to make such selection other than trial and error. It is believed, however, that the following pressures and flow rates are acceptable, at least for trona: at 2000 feet deep, the pressure is 800-900 psi in the cavity **50** and the flow rate is 200-300 gal/min.

In further example embodiments of the invention, the subterranean material **25** is selected from a group consisting essentially of trona, dawsonite, wegscheiderite, nahcolite, thermonatrite, pirssonite, natron, gaylussite, shortite, halite, and other salts, minerals, and so forth.

In various example embodiments, the fluid **10** is selected from a group consisting essentially of water, a caustic mixture, a sodium carbonate solution, or any other fluid **10** capable of

mechanically and/or chemically reacting with the subterranean material **25** to be mined so as to produce a mixture **55** capable of being removed from the production casing **60b** through a production tube **60a**. Such fluids **10** will occur to those of skill in the art. In some embodiments, the fluid **10** is heated.

In a further example embodiment, the mixture **55** is lifted, for example, by pumping with a pump **140** connected to the production tube **60a**, and the mixture **55** is delivered to a collection location **65**, such as the earth's surface **70**. According to one example embodiment, an acceptable pump **140** comprises an electric submersible centrifugal pump, **140** such as those manufactured by Baker Hughes Centrilift. In addition, placement of the pump **140** is above the bed **30** of subterranean mineral **25**, that is, above the mining areas. For example, with trona, the pump **140** is placed in some embodiments about 1100 feet below the earth's surface **70** in the elbow well **15**. Other pumps **140** acceptable for use with the claimed invention include piston/cylinder pumps, driven by sucks rods from the surface **70**. Still other pumps **140** acceptable for use with the claimed invention will occur to those of skill in the art.

Having thus described exemplary embodiments of the invention, it will be apparent that various alterations, modifications and improvements will readily occur to those skilled in the art. Such alterations, modifications and improvements, though not expressly described above, are nevertheless within the spirit and scope of the invention. Accordingly, the foregoing discussion is intended to be illustrative only, and not limiting; the invention is limited and defined by the following claims and equivalents thereto.